

From the  
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

PCT

To:

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NOTIFICATION OF TRANSMITTAL OF  
THE INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing  
(day/month/year)

02.09.2004

Applicant's or agent's file reference

XA1659

IMPORTANT NOTIFICATION

International application No.

PCT/GB 03/02681

International filing date (day/month/year)

24.06.2003

Priority date (day/month/year)

26.06.2002

Applicant

BAE SYSTEMS PLC ET AL.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. REMINDER

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

The applicant's attention is drawn to Article 33(5), which provides that the criteria of novelty, inventive step and industrial applicability described in Article 33(2) to (4) merely serve the purposes of international preliminary examination and that "any Contracting State may apply additional or different criteria for the purposes of deciding whether, in that State, the claimed inventions is patentable or not" (see also Article 27(5)). Such additional criteria may relate, for example, to exemptions from patentability, requirements for enabling disclosure, clarity and support for the claims.

Name and mailing address of the international  
preliminary examining authority:



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# PATENT COOPERATION TREATY

## PCT

### INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference <b>XA1659</b>	<b>FOR FURTHER ACTION</b>	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/PEA/416)
International application No. <b>PCT/GB 03/02681</b>	International filing date (day/month/year) <b>24.06.2003</b>	Priority date (day/month/year) <b>26.06.2002</b>
International Patent Classification (IPC) or both national classification and IPC <b>H03M1/10</b>		
Applicant <b>BAE SYSTEMS PLC ET AL.</b>		
<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 6 sheets, including this cover sheet.</p> <p><input checked="" type="checkbox"/> This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of <b>4</b> sheets.</p>		
<p>3. This report contains indications relating to the following items:</p> <ul style="list-style-type: none"> <li>I <input checked="" type="checkbox"/> Basis of the opinion</li> <li>II <input type="checkbox"/> Priority</li> <li>III <input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</li> <li>IV <input type="checkbox"/> Lack of unity of invention</li> <li>V <input checked="" type="checkbox"/> Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</li> <li>VI <input type="checkbox"/> Certain documents cited</li> <li>VII <input type="checkbox"/> Certain defects in the international application</li> <li>VIII <input type="checkbox"/> Certain observations on the international application</li> </ul>		
Date of submission of the demand  <b>27.12.2003</b>	Date of completion of this report  <b>02.09.2004</b>	
Name and mailing address of the international preliminary examining authority:   European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer  <b>Oliveira, J.</b>  Telephone No. +31 70 340-3334	



**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. PCT/GB 03/02681

**I. Basis of the report**

1. With regard to the **elements** of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17):*

**Description, Pages**

1, 3-12 as originally filed  
2, 2a received on 15.05.2004 with letter of 10.05.2004

**Claims, Numbers**

1-14 received on 15.05.2004 with letter of 10.05.2004

**Drawings, Sheets**

1/2-2/2 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).  
☐ the language of publication of the international application (under Rule 48.3(b)).  
☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.  
☐ filed together with the international application in computer readable form.  
☐ furnished subsequently to this Authority in written form.  
☐ furnished subsequently to this Authority in computer readable form.  
☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.  
☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:  
☐ the claims, Nos.:  
☐ the drawings, sheets:

**INTERNATIONAL PRELIMINARY  
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5. ☒ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

**see separate sheet**

6. Additional observations, if necessary:

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Yes: Claims	1-14
	No: Claims	NONE
Inventive step (IS)	Yes: Claims	1-14
	No: Claims	NONE
Industrial applicability (IA)	Yes: Claims	1-14
	No: Claims	NONE

2. Citations and explanations

**see separate sheet**

Re Item I

Basis of the report

- 1 The following should be noted with respect to the amendments:
- 1.1 The wording in claim 1 "[..] comprising a plurality (N) of time-interleaved ADCs[..]" renders N optional, as it is in parentheses, and thus removes the relation that must exist between the number of time-interleaved ADCs, the calibration signals and the related frequencies. Therefore the parenthesis have not been taken into account.
- 1.2 The amendment in claim 1 (a) "[..] occupies at least one of N related frequencies, [..]" (emphasis added) is not allowable because it does not meet the criteria of Article 34(2)(b) PCT. It is clear from the description as originally filed on page 2 line 23 and on page 3 line 1 - line 8 that the calibration signal should only contain one of the N related frequencies, hence the amendment has not been taken into consideration in this report (in other words the term "**at least**" has been considered as being deleted in claim 1).
- 1.3 The formula introduced in the subject matter of claim 1 is incorrect and the formula on page 2 line 10 in the description as originally filed (the frequency (f) of each of the N related frequencies is given by  $f_{in} + k \cdot f_s / N$ , where  $k=0, 1, 2, \dots, N-1$ ) has been taken into account in this report. Furthermore  $f_{in}$  has thus also to be defined and for the purposes of this report has been considered to be the input tone frequency, as supported by the description page 2 line 7 - line 10.
- 1.4 The same objections apply to claim 11 and to description page 2 line 20 - page 3 line 1.

**Re Item V**

**Reasoned statement with regard to novelty, inventive step or industrial applicability;  
citations and explanations supporting such statement**

Reference is made to the following documents:

- D1:** US-B-6 339,390 (VELAZQUEZ RICHARD J ET AL) 15 January 2002 (2002-01-15)
- D2:** JENQ Y-C: "DIGITAL SPECTRA OF NONUNIFORMLY SAMPLED SIGNALS: A ROBUST SAMPLING TIME OFFSET ESTIMATION ALGORITHM FOR ULTRA HIGH-SPEED WAVEFORM DIGITIZERS USING INTERLEAVING" IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, IEEE INC. NEW YORK, US, vol. 39, no. 1, February 1990 (1990-02), pages 71-75, XP002952453 ISSN: 0018-9456

- 1** **D1**, which is considered to represent the most relevant state of the art, discloses (see Col. 40 L. 40 - Col. 19 L. 29) a method to calibrate interleaved ADCs in which test signals consisting of a comb of frequencies are injected in turn into the interleaved ADCs and then probed to characterise the performance of the interleaved ADCs (errors such as gain mismatches, DC offset and timing mismatches are characterised and the interleaved ADC output signal is related to the input test signal for compensation).

The subject-matter of claim 1 differs in that the comb frequencies which are injected in turn are related according to formula  $f = f_{in} + k \cdot f_s / N$ , where  $k=0, 1, 2, \dots, N-1$ ,  $f_s$  is the sampling frequency and  $f_{in}$  is the input tone frequency. More specifically the injected related frequencies are the spurious frequencies which arise from injecting an input waveform into an interleaved ADC due to gain and sample timing mismatches.

Therefore the subject-matter of claim 1 is new (Article 33(2) PCT).

The problem to be solved could be seen as how to provide an alternate way of calibrating interleaved ADCs such that frequency independent and frequency dependent amplitude and phase mismatches between channels are corrected.

**D2** discloses a method for calibrating an interleaved ADC for sampling time offsets by injecting as test signal one of the related frequencies according to the above formula (the highest below Nyquist frequency). However no mention is made to the injection in turn of different test signals nor using all of the related frequencies for the calibration.

Nor **D1** nor **D2** nor any other document cited in the Search Report disclose the injection in turn of the related frequencies therefore the skilled person would not combine the teachings of **D1** with any other document cited in the search report.

Thus the subject matter of claim **1** is also inventive (Article 33(3) PCT).

- 2      The same applies to corresponding apparatus claim **11**.
- 3      Claims **2-10** are dependent on claim **1** and as such also meet the requirements of the PCT with respect to novelty and inventive step.
- 4      Claim **12** is dependent on claim **11** and as such also meets the requirements of the PCT with respect to novelty and inventive step.
- 5      Claim **13** also meets the requirements of the PCT with respect to novelty and inventive step because the computer is programmed to carry out the novel and inventive method defined in the subject matter of claim **1**.

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DT01 Rec'd PCT/PTC 22 DEC 2004

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## CLAIMS

1. A method of calibrating a sampler comprising a plurality (N) of time-interleaved ADCs, said sampler having an input for receiving an analogue input signal and an output for providing a digital output signal, and the method comprising the steps of:

- (a) injecting in turn N calibration signals into the input of said sampler such that each calibration signal occupies at least one of N related frequencies, where

the frequency (f) of each of the N related frequencies is given by

$$f + k \cdot \frac{f_s}{N}, \text{ where } k = 0, 1, 2, \dots, N-1$$

and  $f_s$  is the sampling frequency of said ADCs

- (b) measuring in the frequency domain the output signal at each of the N related frequencies for each one of the N calibration frequencies; and

- (c) determining the relationship that relates the input signal to the output signal at each of the N related frequencies for each one of the N calibration frequencies.

2. A method according to claim 1, wherein in step (a) each calibration signal comprises a single tone.

3. A method according to claim 1 or claim 2, wherein step (b) further comprises performing an FFT of the digital outputs of the ADCs thereby to allow measurement in the frequency domain of the output at each of the N related frequencies.



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4. A method according to claim 3, further comprising the step of choosing the first of the N related frequencies such that all the resulting N related frequencies have frequencies substantially centred on bins of the FFT .
- 5 5. A method according to claim 3 or claim 4, further comprising the step of repeating steps (a) to (c), injecting in turn N calibration frequencies into the sampler at a different set of N related frequencies.
- 10 6. A method according to any of claims 3 to 5, wherein adjacent bins of the FFT are grouped together and a single calibration frequency used for each group.
- 15 7. A method according to any preceding claim, further comprising the step of forming a relationship matrix, or a relationship matrix for each iteration of the calibration process, to embody the relationship that relates the input signal to the output at each of the N related frequencies for each one of the calibration frequencies.
- 20 8. A method according to any preceding claim, further comprising the step of determining the magnitude and/or phase of the input signal either by independent means or by measuring the magnitude and/or phase in the output of the sampler.
- 25 9. A method according to any preceding claim, including in step (a) determining the magnitude and phase of the input signal for each one of the N calibration frequencies, and wherein step (b) comprises measuring in the frequency domain the magnitude and phase of the output at each of the N related frequencies for each one of the calibration frequencies and step (c) comprises determining correction factors from the relationship that relates

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magnitude and phase of the output at the N related frequencies to the magnitude and phase of the input signal.

5 10. A method of performing an analogue to digital conversion using a sampler comprising N time-interleaved ADCs, wherein the sampler has been calibrated in accordance with the method of any of claims 1 to 9, the method of performing an analog to digital conversion comprising the steps of (i) injecting an analogue signal into the sampler; (ii) measuring in the frequency domain the resulting spectrum produced by the sampler; and (iii) 10 adjusting the measured frequency spectrum in response to the relationships determined during calibration thereby to produce a channel-equalised spectrum.

15 11. A calibration apparatus for calibrating a time interleaved analogue to digital sampler said sampler comprising a plurality (N) of time-interleaved ADCs, said sampler having an input for receiving an analogue input signal and an output for providing a digital output signal, and the apparatus including:

20 (a) means for injecting in turn N calibration signals into the input of said sampler such that each calibration signal occupies at least one of N related frequencies, where

the frequency (f) of each of the N related frequencies is given by

$$f + k \cdot \frac{f_s}{N}, \text{ where } k = 0, 1, 2, \dots, N-1$$

and  $f_s$  is the sampling frequency of said ADCs;

25 (b) means for measuring in the frequency domain the output signal at each of the N related frequencies for each one of the N calibration frequencies; and means for

(c) means for determining the relationship that relates the input signal to the output signal at each of the N related frequencies for each one of the N calibration frequencies.

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12. A channel equaliser for an analogue to digital sampler, comprising the calibration apparatus of claim 11, wherein the said means for determining the relationship is operable to adjust a frequency domain signal derived from output  
5 of the sampler according to the relationships determined during calibration thereby to produce a channel-equalised spectrum.

13. A computer that is programmed for carrying out the method of any of the claims 1 to 10, and to perform the steps of:

- 10 (1) receiving the measurements of the output at each of the N calibration frequencies for each one of the N calibration frequencies;
- (2) determining the relationship that relates the input signal to the output at each of the N related frequencies for each one of the N calibration frequencies.

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14. A computer program product comprising program instructions for causing a computer to operate in accordance with claim 13.